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Subjective and objective assessment of environmental and acoustical quality in schools around Istanbul Ataturk International Airport

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Abstract

Air traffic noise maps have been drawn for Istanbul Ataturk International Airport. With the establishment of these maps, a study was conducted by using subjective and objective methods in order to assess the noise annoyance levels of students and teachers of schools around airport. Questionnaires and intelligibility tests were designed (with different questions for teachers and students) in order to measure the effect of noise among students and teachers as the classrooms' users. A total of seven hundred and twenty (720) students and one hundred and fourteen (114) teachers completed the questionnaire, which was mainly designed to define their ability to differentiate different noise sources (originating both internally or externally), and their annoyance levels with these noise sources. The results reveal that overall, students tend to be more annoyed than teachers; aircraft noise is considered the main external noise source and students' chatter is rated the main internal noise source for both groups. Parallel to the annoyance study, internal and external noise measurements have been carried out to provide information on typical noise levels, to which children are exposed at school. In order to evaluate the acoustical quality of classrooms, four elementary schools within a 5 km radius of the airport were selected and three acoustical parameters have been investigated: background noise level, reverberation time and sound insulation. Finally, in one of the selected school's classrooms, a two-stage improvement study was realised. Results revealed the striking effect of lower reverberation values on increasing speech intelligibility.

Keywords
Noise, Annoyance, School, Classroom, Intelligibility.

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1. Introduction

The acoustic environment is a sound field consisting of background noise and constructive/destructive reflections, and the acoustic character of the environment can have a serious impact on the activities in the respective environment. School buildings must create the acoustic comfort conditions of the learning space and as subject to norms, should offer safety, accessibility and comfort to users (Bernardi & Kowaltowski, 2006). The main requirement for ensuring acoustic comfort conditions is to ensure audibility of the oral communication; the children must be able to understand their teacher and easily establish verbal contact (Sutherland & Lubman, 2001). For this reason, noise is considered the most important environmental pollution problem in schools (WHO, 2001). Over the last thirty years, a number of studies have been carried out to investigate the effect of noise on the school performance and learning abilities of children and to determine the level of annoyance that noise causes. Most research has been focused on the pre-school and elementary school age group, with the objective of determining the chronic impact of various types of environmental noise and noise sources inside the classrooms (Lercher et al., 2003; Klatte et al., 2005; Dockrell &Shield, 2006; Norlander et al., 2005). An intensive investigation of noise levels in 142 schools in London shows that above-standard background noise and poor acoustic conditions in classrooms adversely affect the ability of students to concentrate and follow classes (Shield & Dockrell, 2003; Dockrell & Shield, 2004). Another study has found that children from "quiet" homes, yet taught in noisy classrooms, are less successful on tests than children taught in quiet classrooms (Schick & Meis, 2000). This body of research shows that a noisy environment has a negative impact on attention and memory, as well as an adverse effect on students' ability to follow classes, and perform on written and oral tests. The West London School Study (Stansfeld et al.,2005) concluded that chronic noise exposure is associated with increased noise annoyance levels in children, but the results of the study were not associated with perceived stress or stressful lives. In most of the studies, the experience of teachers in regards to noise has been neglected, even though their performance, in turn, affects students' academic achievements. In a study conducted in different regions of Istanbul with a high level of traffic noise, 146 teachers from 26 schools were asked about their experience. Sixty percent (60%) of participants complained about high ambient noise and poor classroom acoustics which forced them to speak in a loud voice and affected their vocal cords (Bayazıt et.al, 2006; Şan, 2010).

Besides studies on the adverse effect of noise on cognitive abilities and teaching quality, other studies have been dedicated to classroom noise and the improvement of the acoustic conditions. They all show that improvements in the classroom, like the use of acoustic materials or the use of sound amplification systems, have a positive effect on the communication between teachers and students, their motivation, and their verbal skills. At locations with a high noise level, the use of highly insulated windows had a positive effect on lowering the noise level inside the classrooms (Bistrup, 2002; Choi & McPerson 2005,Zannin & Marcon 2007; Hygee,1993).

Through this study, the object was to emphasize the difference between teachers' and students' annoyance levels caused by high exposure levels of airplane noise (Bayazıt, et al., 2009). With the aid of airport noise maps, three high schools and eight elementary schools in regions with noise levels higher than 55 dBA were selected for the study. In order to determine the deviation from acoustic comfort conditions to the current noise level, detailed measurements were carried out at four schools.

Following this study, a three-stage study, including acoustical improvements and detailed intelligibility tests were performed in one of the classrooms of one elementary school, which was located in a highly noisy area (Özgüven, 2015). In the first stage, 3rd and 7th grade students were given sixty (meaningful and meaningless) words and asked to write down what they heard. The existing acoustic conditions were measured concurrently with these tests. At the second stage, after finding out the (word) intelligibility scores of the students, sound absorptive materials were added to the ceiling, thus lowering the reverberation (RT). The tests were then repeated. During the third and final stage, the original windows were replaced with better insulated windows, and intelligibility test was repeated once more. The objectives were to find the relations between intelligibility scores and acoustical quality parameters (reverberation time, sound insulation performance and ambient noise) and develop solutions according to the required levels.

2. Criteria, standards and regulations

Acoustical characteristics of classrooms, like reverberation times and background noise, mainly define the speech intelligibility in classrooms. Excessive background noise and reverberation times deteriorate the signal to noise ratio (S/N) and lead to a reduction in learning efficiency. If children are unable to understand the teacher, the major function of a classroom in providing a transfer of information from teacher to pupil is impaired (Shield & Dockrell, 2003). Indeed, noise in a classroom may originate from external or internal noise sources. Transportation noise around the school site and playground activities are major external noise sources. Student foot traffic in a school's corridors can also be counted as external noise source. Additionally, students sometimes create noise in the classroom during lessons, potentially classifying the students themselves as internal noise sources. Although ambient noise is a defining factor for teaching spaces, for optimum speech intelligibility, teachers' voices should be heard above the background noise (Building Bulletin, 93).

In research and regulations, there is a tendency to define the background noise levels and reverberation times for optimum speech intelligibility; however, it is still controversial to state a single standard value because the speech intelligibility changes depending on the students' ages, hearing abilities, teachers' vocal efforts, overall classroom vol-

Table 1. *Optimum conditions for speech intelligibility standards and regulations of countries on acceptable reverberation time and background noise levels.*

Country	Legislation/Standard	Background Noise Level	Reverberation time
Turkey	T.C. Çevre ve Şehircilik Bakanlığı, 2010	35 dBA (windows closed), 45 dBA (windows open)	n/a
United Nations	WHO, 2001	35 dBA	n/a
United Kingdom	Guideline, Building Bulletin BB93	35 dBA	T_{mf} ≤ 0.6-0.8 s (new) T_{mf} ≤ 0.8-1.0 (refurbisment)
Germany	Standard, DIN 4109	35 dBA (max)	n/a
	Standard, DIN 18041	30-40 dBA	n/a
Australia /New Zealand	Standard, DR AS/NZS 2107	35-45 dBA	0.4- 0.6 s
Spain	Law 37/2003	40 dBA	0.5 s (****) 0.7 s (*****)
Italy	Decree, DPCM 1997	25 dBA, 35 dBA (max)	n/a
Russia	Regulation, SNIP 23-03-2003	40 dBA, 55 dBA (max)	n/a
USA	Standard, ANSI / ASA S12.60-2010 Part 1	(*) 35 dBA (max) (**) 35 dBA (max) (***)40 dBA (max)	(*)T_{mf}: 0.6 s (**)T_{mf}: 0.7 s (***) no requirement
	Standard, ANSI / ASA S12.60-2010 Part 2	(*) 35 dBA (**)35 dBA (***) 40 dBA	(*)T_{mf}: 0.5 s (**)T_{mf}: 0.5 s (***) no requirement
Denmark	Regulation, BR 2010	33 dBA	≤ 0.6 s
Finland	Standard, SFS 5907:en	30- 35 dBA	0.6–0.8 (250–4000 Hz) 50% higher for 125 Hz
Norway	Standard, NS 8175:2008	25-35 dBA	0,6

(*):Core learning space with enclosed volume ≤ 283 m³ (≤ 10 000 ft³)
(**)Core learning space with enclosed volume > 283 m³ and ≤ 566 m³ (> 10 000 ft³ ve ≤ 20 000 ft³)
(***) Core learning space with enclosed volume > 566 m³ (> 20 000 ft³) and all ancillary learning spaces
(****) (no furniture nor people); V< 350 m3
(*****) (including furniture, without people); V< 350 m3
T_{mf}: reverberation time in octave bands with midband frequencies of 500, 1000, and 2000 Hz (s)

ume, and even the acoustic treatment of the classroom. A number of countries have issued regulations and established norms defining the acoustic conditions for learning environments and classrooms, being based on an average level of speaking and hearing performances by teachers and students. The standards, whose objective is to ensure a maximum level in teacher-student communication, define parameters like reverberation time, sound insulation and maximum acceptable background noise. Most countries define the values for background noise criteria with the aid of an 'A' weighted single number indicator. Even though this is a simple and reliable method, this indicator does not include any information about the frequency contents of the noise source. For this reason, for more detailed analyses, it may be more beneficial to use weighted curves that express the information on the spectral noise source levels of the octave band in a single number unit. The most widely used weighted curves are Noise Criteria (NC) and the Balanced Noise Criteria (NCB) curves (Beranek & Ver, 1992) and the Noise Reduction Curves (NR) adapted by the International Organization for Standardization (ISO). The sound insulation-related criteria are expressed in single number ratings (R_w,STC,$D_{nT,w}$) defined over a frequency spectrum (ISO 717, 2013).

In Table 1 and 2, standards and regulations are given by countries. In its Guidelines for Community Noise, the World Health Organisation (WHO) recommends a level of 35 dB (L_{Aeq}) as acceptable background noise for classroom teaching, and 55 dB (L_{Aeq}) for court and playground areas (WHO, 2001).

3. Method

Different methodological approaches (including an environmental noise survey with students and teachers, speech intelligibility tests with students, and internal and external sound measurements to define the acoustical quality) were performed within the scope of the research. A noise survey was conducted in eleven (11) schools. Classroom acoustical conditions were measured in four (4) schools (KST, PHG, AK, NH) and intelligibility study including improvements were performed in one school (PHG). The improvements study consisted of three stage: the first stage was the definition of the existing situation, the second stage was classroom ceiling being covered with sound absorptive materials and floor covered with linoleum, and at the third and last stage, the current windows were replaced with better sound insulated ones (Table 3). Intelligibility tests were repeated after each stage since it was the main parameter needed to judge the effects of classroom conditions on audibility of speech.

Table 2. *Requirements on sound insulation of exterior walls.*

Country	Descriptor	Outdoor equivalent sound level (L_{Aeq}) <60 dBA	60-65 dBA	66-70 dBA	71-75 dBA	>76-80 dBA	Ref.
Belgium	R'_w+C_{tr} dB	22	22	27	27	32	*(Vermeir & Bergh, 2003)*
Holland	R'_w dB	26	26	26	26	26	
France	R'_{route} dBA	35	35				
Germany	R'_w dB	30	35	40	45	50	
İtaly	$D_{2m,nTw}$ dB	≥ 48					Decree, DPCM 1997
Spain	$D_{2m,nTw}$ dB	30	32	37	42	47	CTE DB-HR, 2006

Table 3. *Classroom's changing physical characteristics during the improvement study.*

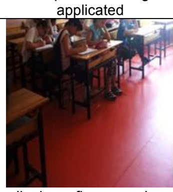
APPLICATIONS		EXISTING MATERIALS	1ST IMPROVEMENT	2ND IMPROVEMENT
	AT CEILING	 plaster + paint, reflective surface	 sound absorptive suspended ceiling applicated	No another/ extra application
	AT FLOOR	 marble floor covering	 linoleum floor covering applicated	No another/ extra application
	ON WALL	 plaster + paint, reflective surface	No application	 Fabric covered acoustic panels applicated
	AT WINDOWS	 Windows with poor sound insulation performance	No application	 Windows were replaced with high sound insulation performance

Table 4. Distance of the schools to the border and centre of the airport.

purple, exposure to the noise > 75 dBA

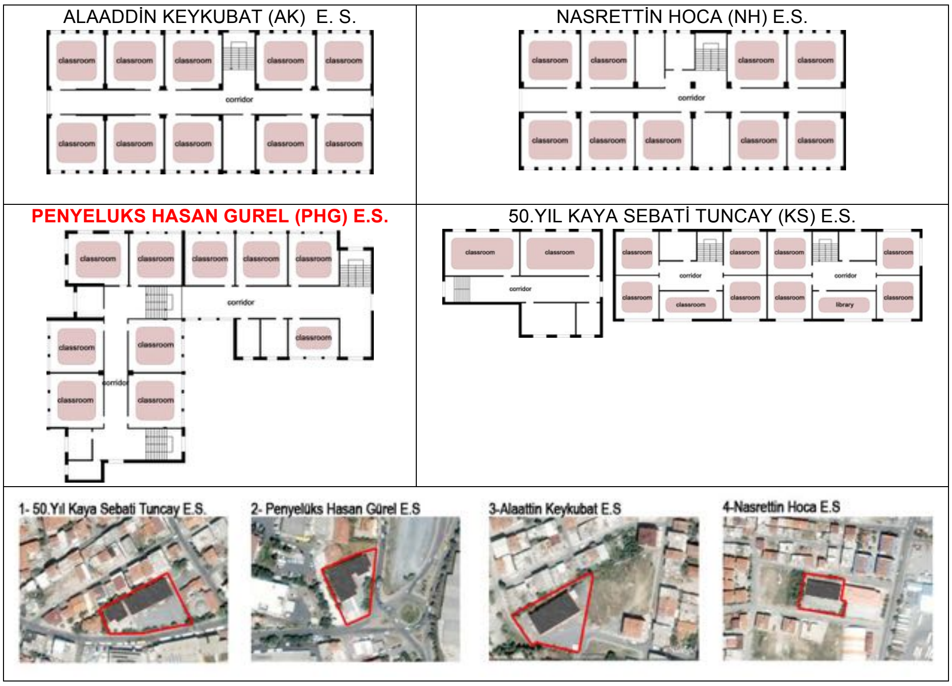
red, exposure to the noise > 65 dBA

NO	SCHOOL NAME	SCHOOL NAME ABBR.	DISTANCE TO THE BORDER OF THE AIRPORT (approx./km)	DISTANCE TO THE CENTRE OF THE AIRPORT (approx./km)
1	**50.Yıl Kaya Sebati Tuncay Elementary School** (*)	**KST**	**0,15**	**2,49**
2	Zeynep Bedia Kılıçlıoğlu Elementary School	ZBK	0,43	1,56
3	Fahrettin Kerim Gökay Anatolian High School	FKG	0,63	2,93
4	**Penyelüks Hasan Gürel Elementary School** (*, **)	**PHG**	**0,78**	**3,05**
5	Şehit Pilot Muzaffer Erdönmez Elementary School	SME	0,96	2,28
6	Altınyıldız Elementary School	A	1,40	3,06
7	Şehit Binbaşı Bedir Karabıyık High School	SBK	1,41	3,71
8	**Alaattin Keykubat Elementary School** (*)	**AK**	**1,90**	**4,20**
9	**Nasrettin Hoca Elementary School** (*)	**NH**	**2,50**	**4,76**
10	Cihangir College	CK	3,54	5,68
11	Mehmet Akif Ersoy High School	MAE	4,21	6,45

(*) KST, PHG, AK and NH were selected for acoustical quality evaluations

(**) PHG was selected for intelligibility study

Table 5. Plan types of schools selected for the evaluation of comfort conditions.



3.1. Selection of the schools

In Turkey, the Regulation on Environmental Noise Control and Management (T.C. Çevre ve Şehrcilik Bakanlığı, 2010) which has been adapted to the EU Directive 2002/49/EC on Environmental Noise (EU Parliament and Council, 2002) applies. According to this regulation, concerning surrounding areas with nearly 50,000 plane landings and takeoffs annually, the noise level in noise-sensitive places (such as educational institutions and health facilities), should not exceed 65 dBA during the day (L_{day}) and 55 dBA at night (L_{night}). If this value is exceeded, measures must be taken at the affected location. Using the Ataturk Airport Noise Map, 11 schools with exposure to more than 55 dBA were selected for the purpose of action plans. The noise exposure levels were measured concurrently with questionnaire surveys. Table 4 shows the selected schools' distance to the border and centre of the airport. The data in the table indicates that school locations are quite close to the airport border.

Four schools were selected for detailed sound quality evaluations. KST, PHG, NH & AK had noise levels between 65-75 dBA, (Table 4). In terms of airport distance, the following ranking (from closest to furthest from the airport) applies: Kaya Sebati Tuncer (0.15 km-2.49 km), Penyeluks Hasan Gürel (0.78 km – 3. 05 km), Alaattin Keykubat (1.9 km – 4.2 km), and Nasrettin Hoca (2.5 km – 4.76 km). These four schools have a plain rectangular shape without any particular architectural features (Table 5). Only PHG underwent a change due to an additional wing to the building itself. However, this change is not visible in the classroom dimensions, which are all approximately 7.0 x 7.0 m.

3.2. Environmental and acoustical quality survey

3.2.1. Questionnaire and intelligibility test design

The student questionnaire consisted of two sections. In the first section, personal questions with respect to their families and achievements in their courses are asked, whereas in the second section, questions regarding noise perception are featured. Questions in the second section are divided into two parts: one concerning their home environment and the other referring to their school environment. The survey aimed to specify whether students perceive noise differently at home or in the classroom, and to be able to analyze whether or not students are annoyed from several external noise sources heard at home and in school at the same level.The students were then asked to rank the most annoying noises on the five point ICBAN scale (Fields et al., 2001).-

For the teachers, a more comprehensive questionnaire (comprising of five pages) was compiled and distributed. The survey had six sections: personal information, classroom acoustical properties, noise sources in the classroom, noise sources outside the classroom, effort to be understood, and general evaluation. The choice of internal and external noise sources on the questionnaire was the same for students and teachers, to ensure comparability. In order to evaluate the effect of open windows, teachers were asked about their vocal efforts in teaching lessons.

The students' intelligibility test was quite comprehensive, consisting of 60 meaningful and 60 meaningless words. The test was administered to third (3rd) and seventh (7th) grade students, who were expected to write down the words they hear (which were said just once). With this test, the goal was to relate the speech intelligibility with the current acoustic conditions of the classroom.

3.2.2. Participants

A total of 544 elementary school students [294 girls (54%) and 250 boys (46%)] and 176 high school students [94 girls (53,4%) and 82 boys (46,6 %)] participated in the survey, which was carried out in eight elementary schools and three high schools around Istanbul Ataturk Airport. 18,3% (99 students) of the participants were 4th graders, 56,4% (307 students) 5th graders, 2% (11 students) 6th graders, and 23% (125 students) were 7th grade students. At the high schools, 34,7% (61 students) of the participants were 9th grade students, 26,7% (47 students) 10th grade,

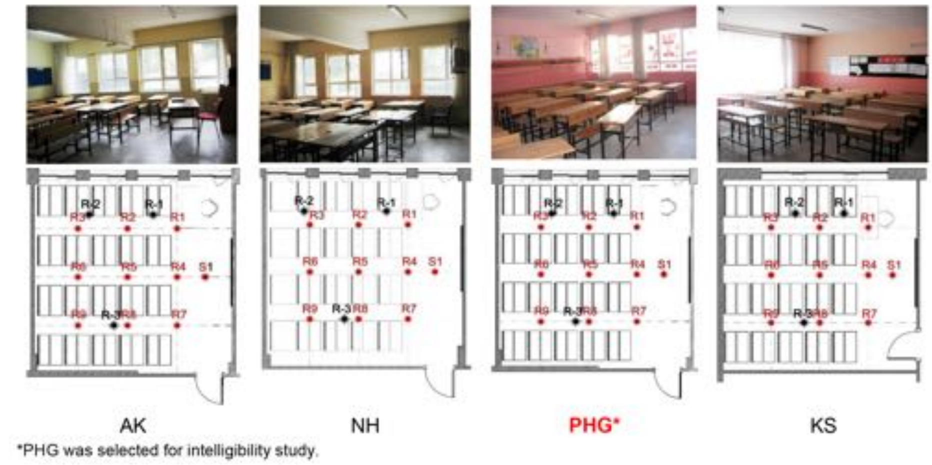


Figure 1. *Plan view of a classroom, showing receiver and source positions. Receiver points shown in letters in black indicate the background noise level measurement positions.*

38,1% (67 students) 11th grade, and 6% (11 students) were 12th grade students.

The teachers' questionnaire was completed by a total of 104 primary school teachers and 10 high school teachers; 50,88% of them were female and 27,19% of them were male. The job experience of the teachers was as follows: 0-1 years, 8,77%; 2-5 years 21,05%; 6-10 years, 29,82%; 11-15 years, 18,42%, and 20,18% had over 16 years of experience.

In Turkey, state schools have double shift education (i.e. the same classrooms are used by different age groups). Therefore, the intelligibility tests were performed in the afternoon with 25 elementary school (3rd grade) and 28 middle school (7th grade) students in the morning hours of the day in the same classroom.

3.2.3. Procedure

The survey was carried out during lessons. Following a preliminary explanation session, the surveyors gave them the questionnaires and the students filled out the forms individually. All students were asked to answer the questions at the same time, and once a question was completed by all students, they all proceeded to the next question. They were allowed to ask questions at any time. Teachers preferred to fill out the forms in the teachers' room during their break time. It took around 25 minutes for the students to complete the forms while the teachers spent around 15-20 minutes with the questionnaires. Only during the intelligibility tests were test words not repeated once.

3.2.4. Measurements

Measurements were carried out with two objectives in mind: to determine the environmental noise level and classrooms' acoustic comfort conditions related to reverberation time, sound insulation and ambient noise levels. The internal and external noise measurements were made on regular school days, while students would be working in the classroom. Internal noise measurements were completed with the windows open and closed therefore, periods of outdoor physical education classes in the playground were also avoided. The measurements designed to determine the acoustic quality conditions reverberation time, sound insulation of the external walls and background noise level measurements.

- Measurements of Internal and External Noise Levels

The noise level measurements were carried out concurrently with the survey in order to correlate them to noise annoyance assessments. External noise values were measured in the school courtsyards in front of the external walls of the classrooms where the questionnaires were completed. All measurements were made during regular school days during hours without extraordinary noise from rain, strong winds, thunder or sports lessons in the open. Internal noise measurements were carried out in classrooms adjacent to, or similarly located to, occupied classrooms, with the windows open and closed. This procedure was chosen, as it would have been rather difficult to keep the class silent during measurements in occupied classrooms. A Bruel and Kjaer (B&K) handheld sound level meter (Type 2260) was used to measure (frequency-dependent) L_{Aeq}, L_{A5}, L_{A90} and L_{A99} according to frequencies; the results were obtained by processing the data with the evaluator software B&K for handheld sound level meters, Type 2260 and B&K 7815 Noise Explorer (The Bruel& Kjaer). All measurements are five-minute samples of interior and exterior noise levels. In determining the number of measurements points and positions, issues specified under TS ISO 1996-2 were taken into consideration average(ISO 1996-2, 2007).

- Measurements of sound insulation

The external walls are the most important structural elements separating the interior from the exterior environment. The measurements were carried out on weekends when the schools were closed for vacation. To measure the inside and outside level differences, two B&K 4160 type microphones were used: one was placed outside facing the facade, and the other inside the classroom. For signal transmission, an AR 0014 flat cable (B&K), which allowed simultaneous noise level measurements, was used. The data collected by B&K 2260 were transferred to the B&K Type 7830 Qualifier software,

Table 6. *Noise annoyance of students' values with comparison of at home and at school.*

	Comparison of **external noise heard** at home and in the classroom			Comparison of **external noise annoyance** at home and in the classroom		
NOISE SOURCE	Home (%)	Classroom (%)	p value	Home (%)	Classroom (%)	p value
Traffic	63,5	58,2	0,040	56	58,2	0,395
Airplane	83,1	80,3	0,173	71,3	77,5	0,006
Noise from playgrounds	81,0	74,0	0,001	64,7	70,0	0,033
Horn and sirens	55,0	49,6	0,039	48,2	45,6	0,317
Street vendors	59,3	32,5	0,000	40,3	29,7	0,000

which processed all the collected data and provided a single number ($D_{2m,nT}$) as the sound insulation index of the facades. Data processing using this program is specified by the ISO 140-5 and ISO 717-1 standard (ISO 140-5, 2006; ISO 717-1,2013). As defined in ISO 140-4 (ISO 140-4, 2006) the required background noise and reverberation time measurements were carried out for the necessary receiver room absorption corrections. Background noise levels were measured in 3 different positions in the classrooms. For the improvement study, the existing windows were replaced with a better insulated windows and all measurements were repeated with the same method.

- Measurements of reverberation time

To measure the reverberation time, a two channel BK 2260 modular real time sound analyser was used, which emits a pink noise signal to a B 2716 power amplifier connected to the sound source. A BK 4296 omni-directional dodecahedron sound source was used. The generated sound was captured by a microphone connected to the BK 2260 analyser, which automati-

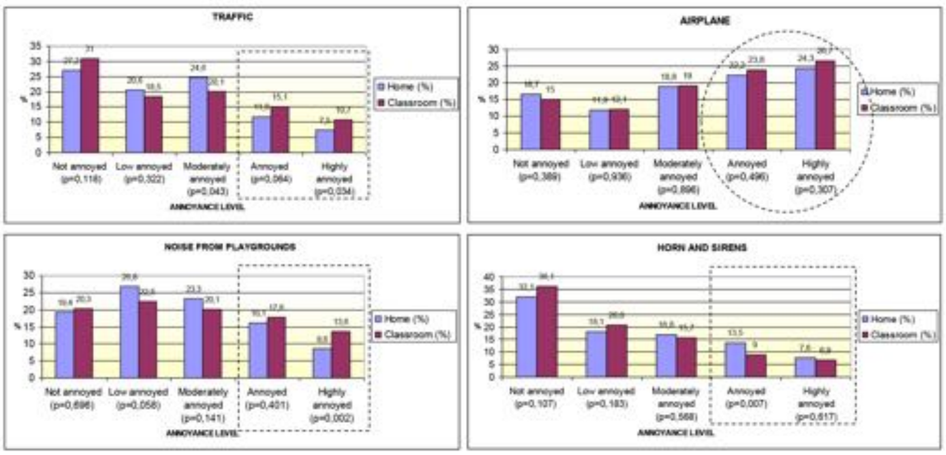


Figure 2 . *Comparison of external noise annoyance level at home and in the classroom.*

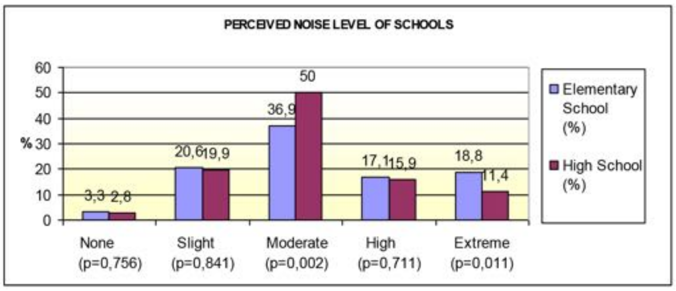


Figure 3 . *Perceived noise level of schools between elementary and high school.*

cally calculated the reverberation time as RT60 for each frequency of interests. Measurement positions were in seats, at average ear height, 1.1 m above the floor. Since the four classrooms were of similar size, the current receiver positions represent the same receiver positions. At each position, and in octave bands from 125 to 4000 Hz, reverberation times were measured. In the laboratory, measurements were then transferred to a computer using Qualifier 7830 software from B&K, which calculated the mean RT and the respective standard deviation for each evaluated frequency. This procedure was repeated for each classroom in which RT was measured. The reverberation time values of four (4) different classrooms in four (4) different schools were measured in nine (9) different positions (Figure 1). The classrooms have a volume of 140-150 m^3 and each have a capacity of 40 students. Measurements were done according to ISO 3382 (ISO 3382-1, 2009).

3.2.5. Statistical analysis

For statistical analysis of the questionnaire, SPSS Ver. 15.0 was used (IBM, SPSS). In order to compare students' and teachers' answers about noise annoyance, a Z-test was performed with the null hypothesis, which plays a major role in testing the significance of differences in control groups. In the survey, it is stated for the null hypothesis that there is no significant difference between the averages of the two groups (H_0: $\Pi_x = \Pi_y$), where Π represents the percentages and x&y represents the groups; for the alternate hypothesis, it is stated that there is a significant difference between the averages of two groups (H_1 : $\Pi_x \neq \Pi_y$). Besides, p-values were calculated to evaluate the "statistical significance" of the data. The p-value is the probability of rejecting the null hypothesis when that hypothesis is true. In this study, p-values were tested within a confidence interval of 0,05 (5%), and if p<0.05, the null hypothesis is rejected, which means that there's a meaningful or important difference between the two groups (Ünver & Gamgam, 2008).

Table 7. *External noise heard and noise annoyance during lesson of elementary school students' values with comparison to high school students' values.*

	Comparison of external noise **heard** in elementary and high school students in the classroom **during lesson**			Comparison of external noise **annoyance** in elementary and high school students in the classroom **during lesson**		
NOISE SOURCE	Elementary School (%)	High School (%)	p value	Elementary School (%)	High School (%)	p value
Traffic	58,1	58,5	0,920	59,2	55,1	0,347
Airplane	81,4	76,7	0,190	80,3	68,8	0,003
Noise from playgrounds	73,9	74,4	0,888	73,3	59,7	0,001
Horn and sirens	48,7	52,3	0,412	45,8	44,9	0,841
Street vendors	31,3	36,4	0,218	29,2	31,3	0,617

4. Findings

4.1. Findings with respect to questionnaires

The questionnaires for elementary and high school students and teachers were both evaluated separately for each group and later compared with one another. Based on their responses, the level of awareness and annoyance of students and teachers regarding particular forms of environmental noise at home and at school were analysed. The most annoying external noise sources were identified as traffic, airplanes, trains, industrial noise, noise from playgrounds, construction sites, animals, and horns, respectively. The survey also included questions on internal noise sources with a negative impact on lessons; they were identified as students talking with each other, the moving of desks and chairs, audio-visual equipment, lighting fixtures, noise from corridors, noise from other classrooms, and noise from outside.

4.1.1. Students responses

- Ability to differentiate noise at home and at school

An examination of students' noise annoyance ratings of noise at home and at school finds airplane noise in the first place, followed by noise from playgrounds, traffic, horns, sirens,

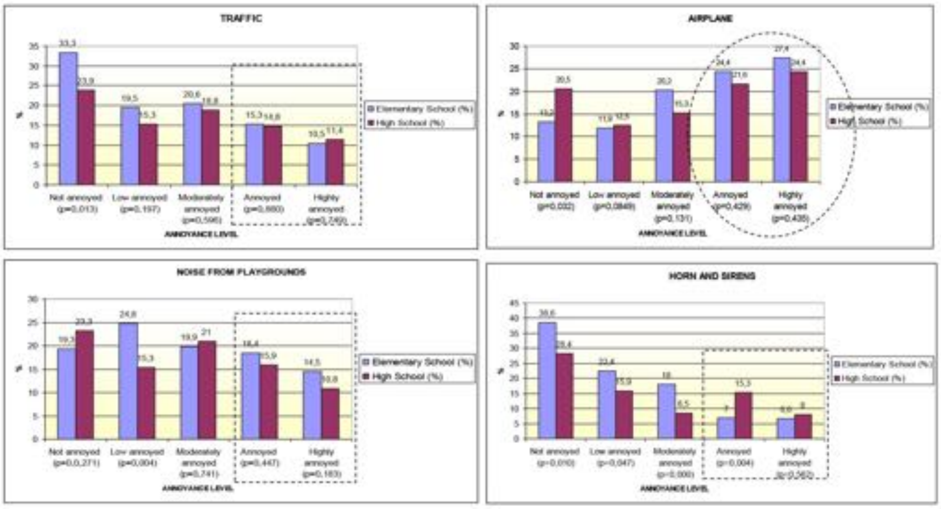


Figure 4 . Comparison of external noise annoyance level in elementary and high school students in the school during lesson.

and street vendors' noise. Comparison of the noise ratings at home and in the classroom revealed a statistically significant difference between home and school, with noise heard at home being rated less annoying than the same noise source heard at school. The only difference is airplane noise, which is rated equally high (Table 6). The reason for this may be that there are many agents, which affect student's attention concerning noise at school. Through a comparison of noise annoyance caused by airplanes, traffic, noise from playgrounds, horns, and sirens at home, and those noise sources in the classroom, no significant difference was found, statistically. Students are annoyed by noise sources at the same degree, as they hear them. As indicated in the previous research, this result reveals that they are more sensitive to noise in the classroom while trying to follow their lessons (Shield & Dockrell, 2003; Dockrell & Shield, 2004).

When degrees of noise annoyance are examined, students are bothered by airplane noise above the moderate level both at home and at school, while annoyance levels of other noise sources are below the moderate level. When comparing the home and classroom environments, it was found that all external noise sources (except horns and sirens) disturb students significantly more when they are in school. Students' abilities to compare and report the annoyance caused by different noise sources explicitly puts forward that children are aware of the noise problem and struggle while learning because of high noise levels (Figure 2).

- Comparison between elementary and high school students' responses

In response to the question of evaluating the noise levels at the location of their schools, most of the elementary and high school students defined their schools as *moderately* noisy, given that their schools are in a moderately noisy region (Figure 3). But the ratio of the elementary school students who find their schools located in an extremely noisy location is significantly more than the high school students.

When the percentages of the noise heard among elementary and high school students at school are analysed, the highest rated noise source is airplane noise, followed by noise from playgrounds, traffic, horns and sirens, and street vendors. A comparison of the student groups yields no statistically significant difference. This indicates

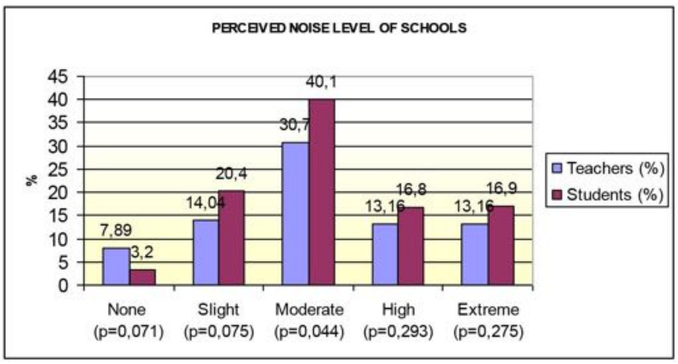


Figure 5 . Perceived noise level of schools between teachers and students.

Table 8 . External noise heard and noise annoyance of students' values with comparison to teachers' values.

	Comparison of external noise **heard** in students and teachers in the classroom during lesson			Comparison of external noise **annoyance** in students and teachers in the classroom during lesson		
NOISE SOURCE	Teachers (%)	Students (%)	p value	Teachers (%)	Students (%)	p value
Traffic	36,84	58,2	0,000	29,82	58,2	0,000
Airplane	85,09	80,3	0,190	72,81	77,5	0,293
Noise from playgrounds	64,04	74,0	0,037	41,23	70,0	0,000
Horn and sirens	36,84	49,6	0,009	29,82	45,6	0,000
Street vendors	18,42	32,5	0,000	14,04	29,7	0,000

that age does not affect students' awareness of noise sources at school. In a comparison of the student groups with respect to annoyance at school (caused by traffic, horns, sirens, and street vendor noise), again, no statistically significant difference was found. But elementary school students are more annoyed by airplanes and noises from playgrounds while in the classroom than high school students. A comparison of the percentages of annoyance shows that high school students are less annoyed by noise heard at school, while elementary school students are annoyed by noise sources at school to the same degree as they hear them. This result indicates that elementary school students are more sensitive to noise in the classroom - while they are trying to concentrate on lesson - than high school students (Table 7).

As to the annoyance degree levels, elementary and high school students are annoyed by airplane noise at school to an above moderate level, while annoyance caused by other noise sources is below the moderate level. The highest maximum percentage of both elementary and high school students who are highly annoyed by airplane noise show no significant difference (p: 0,435 > 0,05 for airplane noise) (Figure 4).

- Teachers responses

With respect to internal noise sources, teachers registered students talking among each other during classes (64.91%) as the predominant noise source; this was followed by noise from outside (64.04%), noise from the corridor (50.00%), noise from shuffling chairs and tables (49.12%), noise from adjacent classrooms (43.86%), noise from audio and video devices (31.58%), and noise from lighting fixtures (12.28%). Teachers were also asked about the annoyance of the noise they heard with the following results: outside noise: 52.63%; students talking among each other during lessons: 51.75%; shuffling of chairs and tables: 39.47%; noise from the corridor: 37.72%; noise from adjacent classrooms: 33.33%; noise from audio and video devices: 14.91%; noise from lighting fixtures and the HVAC system: 7.89%. With regard to their vocal efforts, 66.67% stated that a normal voice level was sufficient to be understood during lessons, while 31.58% stated that they had to raise their voices. Most teachers (52.63%) stated that they used teamwork as a teaching method, and that they had to raise their voices during such classes. 57.89% of teachers stated that they had to raise their voices to be sufficiently understood, particularly during flyovers, and that this put a serious strain on their vocal cords and had subsequent health consequences.

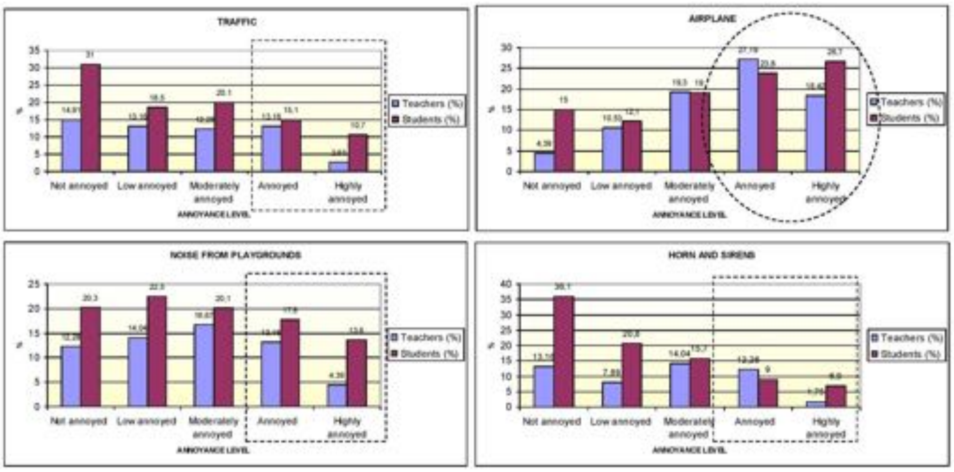


Figure 6 . Comparison of external noise annoyance level in students and teachers in the classroom during lessons.

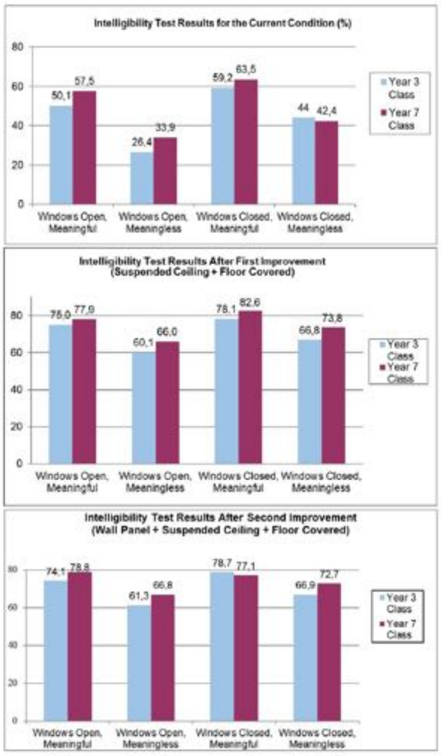


Figure 7 . Comparison of the intelligibility test results (%).

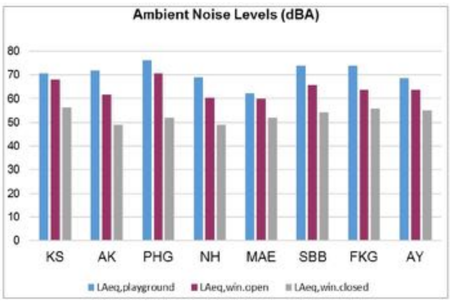


Figure 8. Ambient noise levels measured during questionnaire survey.

- Comparison between teachers and students' responses

Students and teachers answered the question about the perceived noise level at the location of their schools as moderately noisy (Figure 5). However, a high percentage (83,5% of students and 56,14% of teachers) expressed the wish to have a quieter school location.

An examination of the percentages of noise heard and the noise annoyance of students and teachers identifies airplane noise as the highest rated noise source followed by playground noise, traffic, horns, sirens, and street vendor noise (Table 8). Teachers tend to be less annoyed by external noises than students except with regards to airplane noise. This result indicates that students are more sensitive to noise in the classroom than teachers while trying to understand the information taught by the teacher.

A closer look at the annoyance levels shows that the numbers of students and teachers annoyed by airplanes are above the moderate level, while annoyances caused by other noise sources are rated below the moderate level. The annoyance percentages for students and teachers are highest for airplane noise, with students being more annoyed than teachers (Figure 6).

Table 9. *Descriptive statistics of noise levels.*

			L_{Aeq}	L_{A5}	L_{A90}	L_{A99}	L_{Amax}	L_{Amin}
External noise		Mean	70,6	73,8	61,9	59,7	81,8	60,2
		Std. Deviation	4,3	4,9	3,9	3,8	6,5	4,0
		Range	14,1	16,5	11,6	11,0	20,7	10,9
		Minimum	62,1	64,0	56,8	54,3	70,4	54,8
		Maximum	76,2	80,5	68,4	65,3	91,1	65,7
Internal noise	Windows open	Mean	64,2	67,2	56,9	54,8	75,4	55,5
		Std. Deviation	3,7	3,8	4,3	4,3	3,8	4,4
		Range	10,6	11,0	10,8	11,2	11,2	11,5
		Minimum	59,9	62,1	51,5	48,8	71,0	49,4
		Maximum	70,5	73,1	62,3	60,0	82,2	60,9
	Windows closed	Mean	53,0	55,6	46,6	44,5	63,6	45,0
		Std. Deviation	2,9	3,5	4,4	4,4	4,3	4,5
		Range	7,4	9,6	10,3	10,9	11,8	10,4
		Minimum	49,0	49,9	40,6	38,6	57,2	39,1
		Maximum	56,4	59,5	50,9	49,5	69,0	49,5

4.2. Findings with respect to intelligibility tests

As part of the improvement study, the same intelligibility tests were used during the study. As can be seen from the results of the test scores, changing the classrooms' physical attributes by applying an absorbent suspended ceiling remarkably increased the speech intelligibility scores (Figure 7). When windows were open, the intelligibility

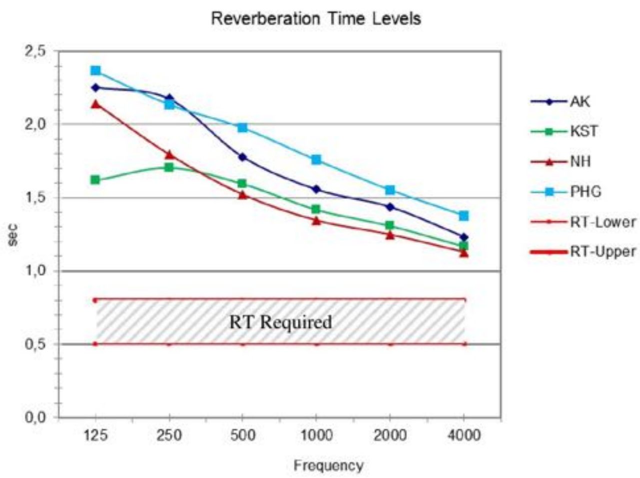


Figure 9. Reverberation Time levels of four classrooms.

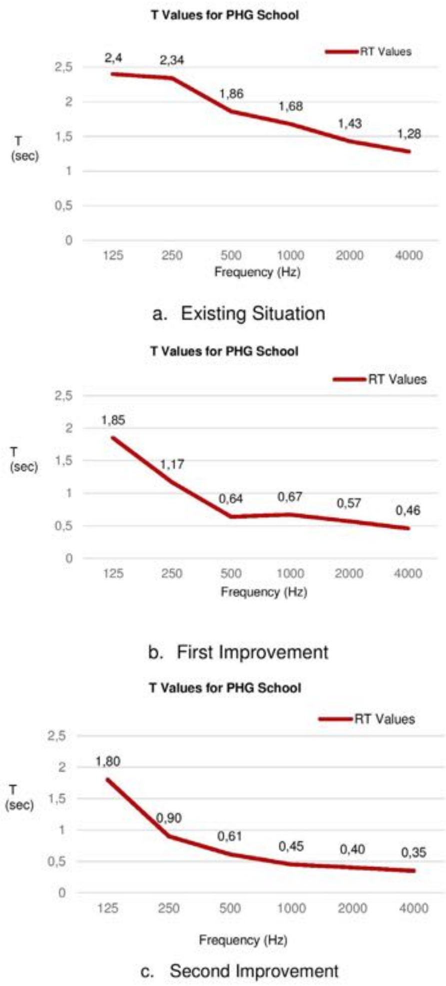


Figure 10. *Comparison of the reverberation time values obtained after the improvements.*

scores of meaningful and meaningless words increased from 25% to 34% for 3rd graders, and jumped from 20% to 33% for the 7th graders, after the first and second improvement. During the winter season when the windows were closed, the intelligibility scores of meaningful and meaningless words increased from 20% to 23% for 3rd graders and from 13% to 31% for 7th graders. As can be seen from Figure 7a, the effect of the first improvement (lowering the RT to an acceptable level) on the speech intelligibility scores is more when compared to the scores tested after the second improvement (increasing the sound insulation characteristics of facade by changing the windows). These results prove that providing an absorptive environment is the key attributes to ensure the audibility of oral communication in the classroom.

4.3. Findings with respect to measurements

4.3.1. Noise levels

The environmental noise parameters, which were recorded at each site for 5 minutes, are the (internal and external) ambient sound levels ($L_{Aeq,5min}$) and the background noise levels (L_{A5}, $L_{A90,}L_{A99}$), which indicate the noise characteristics of the local environment. A weighted (maximum and minimum) sound levels were also noted. External noise levels were measured outside the school buildings in the playground area. Where possible, the measurements were conducted in front of the noisiest facade of the school building. L_{A5} indicates the highest levels, L_{A90} symbolizes the background noise, L_{A99} the underlying levels, L_{Aeq} the ambient levels, and L_{Amax} and L_{Amin} the highest and lowest level, respectively (to which the schools are subjected). Since state schools have no HVAC systems, they teach with open windows during the summer. For this reason, the internal noise levels were determined with open and closed windows separately. The parameters of 5 minute measurements during lessons in classrooms with open and closed windows are shown in Figure 8. On the playground, the most commonly occurring noise levels are in the range of 62 - 76 dB L_{Aeq}. With open windows, the values ranged from 59-75 dB, while closed windows reduced the internal noise level by about 10 dB.

Considering all schools together, standard deviations, means, and ranges of the measured parameters are shown in Table 9. There is a relatively small difference between L_{A5} and L_{A90} (12,1 dB); it is not typically expected during the day in a noisy area. It can be seen that, for most parameters, the standard deviation is approximately around 5.5-6.3 dB. The greatest variation in levels occurs for the L_{Amax} levels, with a high standard deviation of approximately 7 dB. The L_{Amax} measured during a 5 min. period reflects the occurrence of individual events with noise levels higher than the ambient noise. This parameter would therefore be expected to demonstrate the widest variation of all parameters.

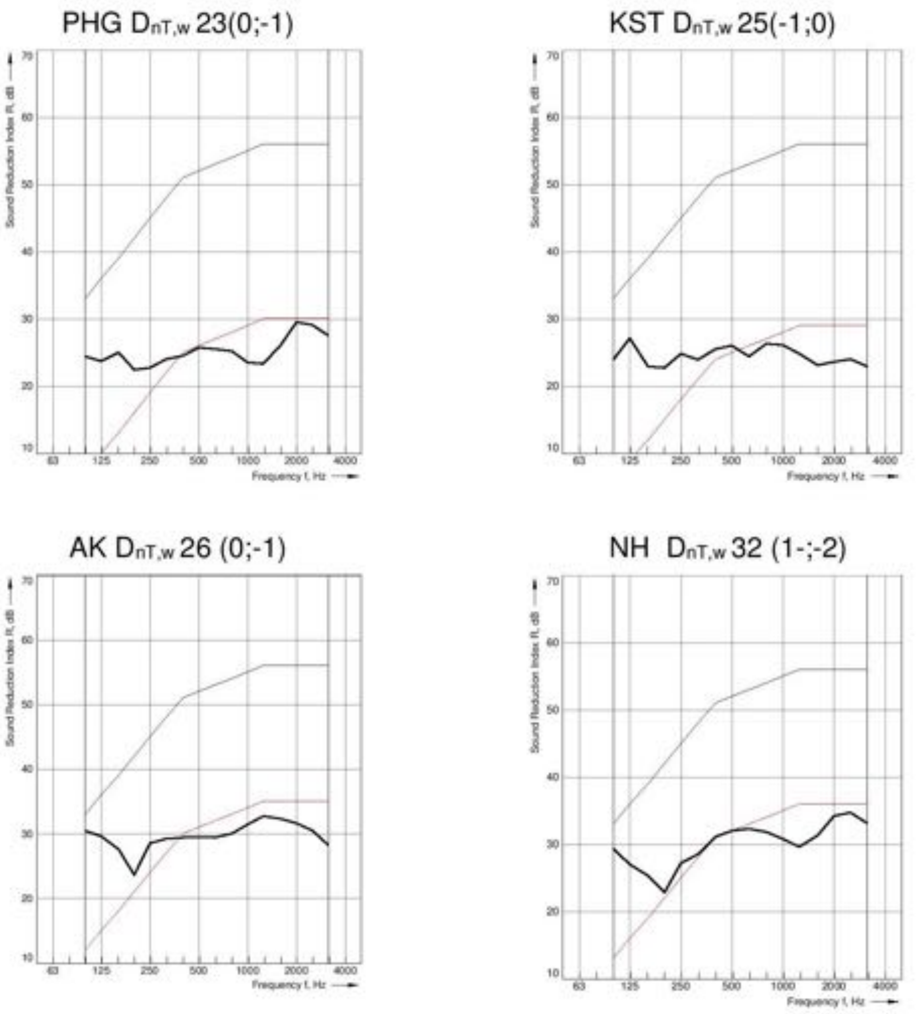
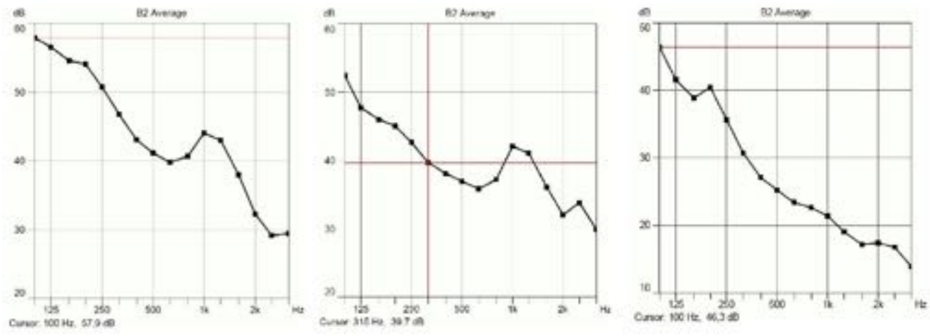


Figure 11. Current weighted standardized level difference values of façades.

4.3.2. Reverberation time measurements

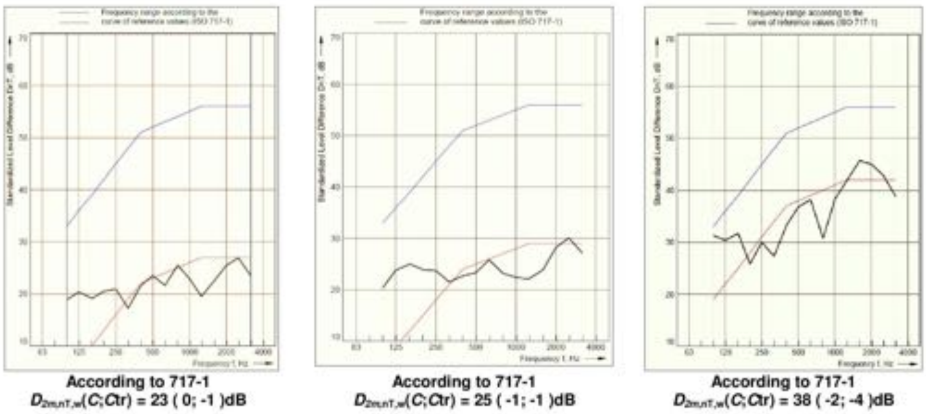
Figure 9 displays the RT values for four evaluated classrooms. The volume of the classrooms was around 140 m^3. When compared with the limit values established by different standards or regulations, the acoustical quality conditions all the schools are excessively higher than the required limits as defined in Table 1. Research shows that the presence of students has a positive influence on the reduction of RT values, but that it also causes reduced signal levels and increased background noise due to student activities. In the current situation even though these values would be expected to drop when students are present, sound absorbing materials would have to be added to classroom surfaces. The measured RT values show the lack of acoustic comfort in the classrooms. The acoustic deficiency in these spaces impairs communication between students and teachers, since high RT diminishes the intelligibility of speech.

Figure 10 shows the comparison of reverberation values which were measured before and after the improvement of the classroom physical conditions. During the first improvement, the ceiling was covered with a (OWA Bolero Acoustic) Rockwool suspended ceiling and the terrazzo floor covered with linoleum floor material to prevent the excessive noise level created due to the students' activities during class time. As the second improvement was mainly designed to lower the excessive ambient noise penetrating from the facade, the replacement of the windows doesn't changed the reverberation time too drastically. The slight variations in the RT values are caused by the absorptive wall panels applied to one of the side walls. As can be seen from the graphics, after the second improve-



a. Existing Situation b. First Improvement c. Second Improvement

Figure 12. *Comparison of weighted standardized level difference values of façades.*



a. Existing situation b. First improvement c. Second improvement

Figure 13. *Comparison of background noise levels.*

ment, the required reverberation time values were provided in the classroom as defined in the regulations.

- Sound insulation measurements

Although several authors state that ambient noise levels and reverberation time are the most important parameters that affect the acoustic quality of classrooms, sound insulation should not be disregarded. Sound insulation should be a priority in school environments where the noise sources cannot be altered, especially in schools affected by high levels of noise from road, air, and railroad traffic. Due to the complexity of the measuring process (in terms of the quantity of equipment and number of people involved), sound insulation measurements were taken in only four of the eleven schools. After the field measurements, the data was transferred to the Qualifier software (B&K 7830), which processes all the data collected and provides a weighted standardised level difference values ($D_{2m,nT,w}$) of façades (Figure 11). The facade is composed of double-glazed windows and a brick wall. The standardised sound insulation values ($D_{2m,nT,w}$) of four schools differ between 25-32 dB. The required sound insulation of facades recommended in Table 2 ranges between 37-42 dB for schools having external noise of 65-70 dBA as in this study. The insulation value recommended by ANSI S12.60-2002 is 50 dB (ANSI/ASA S12.60,2009). The values obtained for $D_{2m,nTw}$ are far below the desired sound insulation of facade levels and far below the desired level specified in different countries' standards (Table 2). Comparisons of weighted standardised level difference values ($D_{2m,nT,w}$) are given in Figure 12.

During the improvement study to test the intelligibility of students in PHG elementary school, average ambient noise levels were measured 48,7 dBA for existing situation, 44,0 dBA and 32 dBA respectively after the first and second improvements (Figure 13). As can be seen from the third graphic, applying a better sound insulated windows has provided the required background noise levels as requested in the regulations given in Table 2. With the new windows, background noise levels were decreased to 32 dBA when the windows were closed.

5. Conclusion

To evaluate school noise perception and acoustic conditions, elementary and high school students and their teachers at eleven schools around Istanbul Ataturk Airport were asked to complete a questionnaire. It was found that these two main groups of occupants were subject to high levels of ambient noise mainly caused by aircraft traffic. Measurements of ambient noise revealed an unacceptably high level of noise in the classrooms; in some schools, the average noise level was found to be as high as 65 dBA when the windows were open. The measured levels exceeded the limits defined in the EU Directive 2002/49/EC and other national norms. Not a single classroom was within the recommended limits.

High ambient noise is an attention distracting factor in the acoustic environment of classrooms and affects the level of concentration, attention, participation, and specifically speech perception with regards to learning, reading, writing and spelling abilities of students (young children at elementary schools in particular). The answers to questions on noise awareness and noise annoyance, which were gathered simultaneously with noise measurements, show that students and teachers are sensitive to similar sources of noise. However, aircraft noise was found to be the main cause of annoyance compared to other noise sources. With respect to a moderate level of annoyance, aircraft noise was rated well above moderate, while all other noise sources were rated below moderate. At home, students are as annoyed by noise as they are at school, but at home, they are also more sensitive to it. Among the student groups, elementary school sudents were found to be more annoyed by noise in the classroom than high school students, who are in general more affected than their teachers. This study's results show that external noise both distracts and annoys students and, in particular, the negative state of mind caused by noise may have a long-term impact on their learning ability.

Teachers' performances also suffer as a result of noise due to its interference in the oral transmission of information, and thus, the teaching process. In the worst cases, it may even affect their vocal cords, as teachers have to raise their voices to be heard above the competing outside noise. However, despite the fact that teachers are more sensitive to noise sources, students seem to be more annoyed by noise than teachers. Though it should be the teachers' task to inform students about the adverse effects of noise and how to protect against it; this is one of the important social results of this study which requires a more detailed analysis. This survey indicates that schools exhibit inadequate acoustic conditions for the reduction of noise. Insufficient sound quality and air tightness of windows are the main obstacles to noise reduction. The teachers of the classroom in noisy areas tends to shut windows especially during quiet activities to reduce the effect on teaching of aircraft noise as well as other external noises. This may cause an increase in the likelihood of students relate the classroom experience overheating in hot weather and poor air quality due to the lack of insufficient ventilation.

The acoustic measurements and physical evaluation of classrooms revealed none of the classrooms exhibited the use of acoustically modified furniture partitions, drapes or acoustical ceiling tiles, or carpeting, which are the most effective measures in noise reduction. The lack of appropriate acoustical measures in the classrooms was apparent. Interviews with students and teachers have shown that apart from external noises (mainly aircraft originated) the main noise sources noted in the classroom originate inside the school. The findings of the improvement study, exhibited that the use of sound absorbing materials were found quite effective in increasing the speech intelligibility and reducing the classroom internal noise level.

As a final result of the study, it can

be said that while the investigating the effect of environmental noise on children, a wide range of performance factors and different noise sources must consider. Ensuring conditions concerning acoustic comfort at schools within noisy environments (such as those near airports) requires costly upgrades which may not always be successful. For this reason, before taking any noise-reducing action, the effect of airplane noise should be determined and the measures should be adapted to the prevalent noise level, accordingly.

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